Bacterial Cell Envelopes and Antibiotics

Resource Type: Curriculum: Classroom

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Abstract

This activity has two parts: the first is meant to get students focused on bacterial cell structure; the second involves analytical thinking and data interpretation. In the first part, students are given diagrams of three cell envelopes (from a gram positive, gram negative, and archaeal cell) to label. In the second part, students are given some information about two antibiotics (polymyxin and vancomycin) and the results from two experiments. Based on the data and their knowledge of cell envelope structure, they predict which experiment reflects data from which antibiotic.

Activity

Invitation for User Feedback. If you have used the activity and would like to provide feedback, please send an e-mail to MicrobeLibrary@asmusa.org. Feedback can include ideas which complement the activity and new approaches for implementing the activity. Your comments will be added to the activity under a separate section labeled "Feedback." Comments may be edited.

INTRODUCTION

Pedagogical Function.
This activity was designed to reinforce students' knowledge about cell envelopes, to allow students to use this knowledge to interpret experimental results, and to get students to synthesize their knowledge by explaining the results.

Background.
Students should have been exposed to the basic structure of the various prokaryotic cell envelopes (gram positive, gram negative, and archaeal).

PROCEDURE

Materials.
Small Group Activity Part I, Part II, and Writing Assignment (PDF)
Small Group Activity Answer Key (PDF)

Instructor Version.
1. We put students in groups of three to four people and give them Part I. Students can use any resources they have and are encouraged to talk with each other. The role of the instructor is to answer questions or give minimal assistance to groups going in the wrong direction. After 15 minutes, the entire class comes together to go over the correct answers.

2. Students then get Part II. Again, students can use any resources they have and are encouraged to talk with each other. This time, they must agree on the answer to the question and write it up individually. This answer gets handed in for a grade.

Safety Issues. None.

ASSESSMENT and OUTCOMES

Suggestions for Assessment.
While a final answer is handed in for a grade, the goal of this activity is that all students have the correct answer figured out before they leave. This activity is not meant as an assessment but as a process that helps students learn.

Field Testing.
We have used this activity for three years and students find it enjoyable, relevant, and helpful. The evaluation from fall 2000 is included below:

1. During the *first* small group, you compared the structure of gram positive bacterial, gram negative bacterial, and archaeal cells. You also analyzed data regarding antibiotics and how they affected these cells. The goal of this activity was to help you better understand the prokaryotic cell structure. How well was this goal met?

Student responses

Very well	Partially	Poorly	Not at all	I did not attend
63	17	2	0	1

Problems and Caveats.
Groups need to come in and get to task relatively quickly to allow enough time to finish within the 50 minute period. Part I and Part II take us about 20 minutes each.

SUPPLEMENTARY MATERIALS

References.
Sherris, J., (ed.). 1990. Medical microbiology: an introduction to infectious disease, 2nd ed. Elsevier Science Publishing, Inc., New York, N.Y.

Small Group Activity
Cell Structure and Function

Part I (20 minutes)
Throughout the activities today, you will work in groups of three to four students.
You may use whatever resources you have available.

1) In your group, look at the diagrams on the next page of three different prokaryotic cell envelopes. Determine which cell envelope shows a gram positive, proteobacterial or gram negative, and archaeal cell envelope.

2) Label the components of each cell envelope using the list below.
(Note: not all cells have all the structures listed)

peptidoglycan	lipopolysaccharide
cytoplasmic membrane	periplasmic space
outer membrane	phospholipid bi-layer
membrane-bound protein	teichoic acid
porin	polysaccharide cell wall

3) Compare and contrast the three different cell envelopes considering the **function** of each structure.

a) Which three general structures do they ALL have in common? (Choose from the list below.)

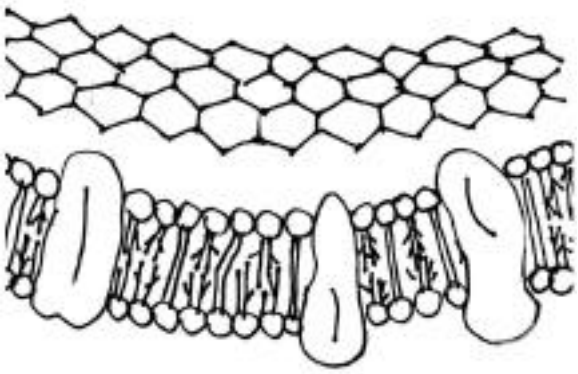
cell wall	lipopolysaccharide
periplasmic space	teichoic acid
outer membrane	cytoplasmic membrane
porin proteins	peptidoglycan cell wall
membrane-bound proteins	

b) What is the function of each of these three structures?

Cell type _____

outside cell

protein
"S-layer"



cytoplasmic membrane

inside cell

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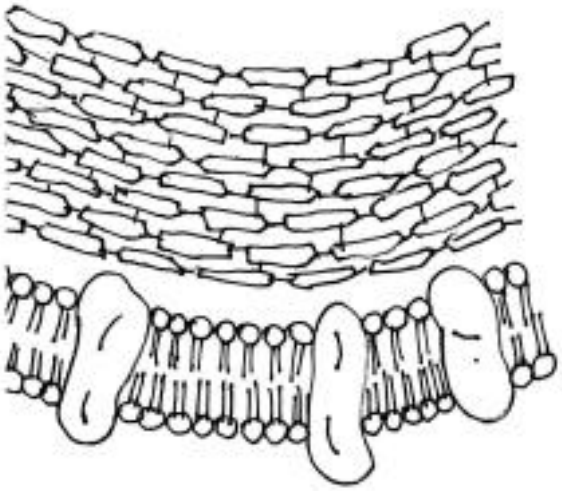
outside cell

Cell type _____

peptidoglycan



cytoplasmic membrane

inside cell

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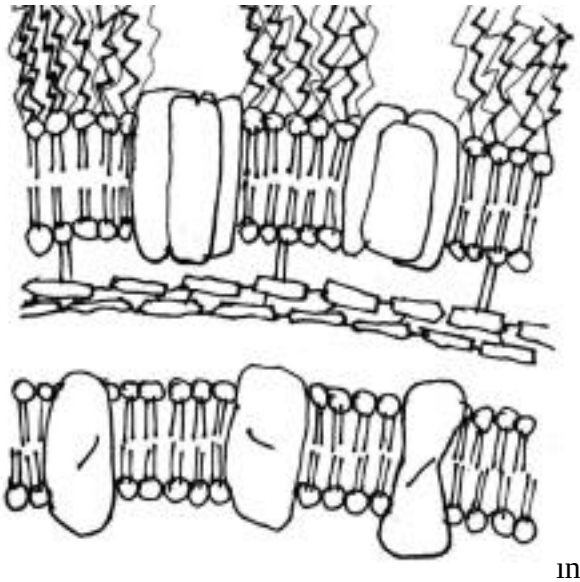
outside cell

Cell type _____



peptidoglycan

cytoplasmic membrane

inside cell

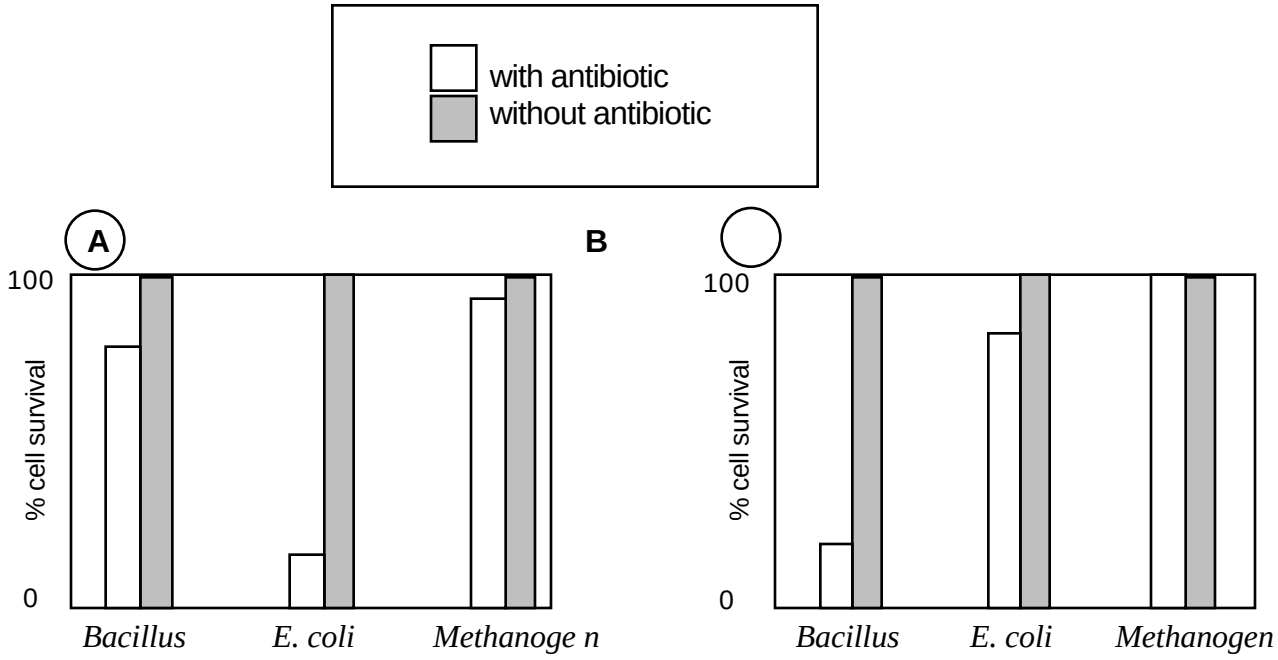
Small Group Activity
Cell Structure and Function

Part II. (25 minutes)
Antibiotics are organic chemicals that selectively kill bacterial cells (without harming eukaryotic cells). Many antibiotics work by attacking and disrupting different parts of the bacterial cell envelope.

For example, **vancomycin** is an antibiotic that has become critical for controlling penicillin-resistant bacteria. This large glycopeptide (molecular wt. = 1449) binds to **cell wall precursors** and interferes with peptidoglycan synthesis.

The **polymyxins** are a group of antibiotics that are particularly effective as a topical antibiotic against skin infections. These large polypeptides (molecular wt. = 1202) can disrupt some bacterial membranes by binding preferentially to **lipid A molecules**.

In the experiments below, different prokaryotic cells were grown in broth cultures in the presence or absence of an antibiotic (either vancomycin or polymixin) After 1 hour, cells were rinsed, and the percent of bacteria that survived was determined.



Using the data above, **predict** which experiment (A or B) was done using vancomycin and which experiment was done using polymyxin, and **explain your rationale**.
NOTE: *Bacillus* has a Gram (+) type envelope; *E.coli* has a Gram (-) type envelope and *Methanobacterium* is an Archaea. (Hint: think about cell envelope structure).

Once you come up with an answer that everyone in your group agrees with, **write it in on the attached sheet and hand it in to your instructor.**

Small Group Activity
Cell Structure and Function
Writing Assignment

Your name _____

Your instructor's name _____

QUESTION: According to the data on the previous page, which experiment (A or B) was done with vancomycin and which was done with polymyxin?

For full credit (5 points), you must explain your reasoning in both cases.

Please limit your answer to the FRONT of this page.

Small Group Activity ANSWER KEY
Cell Structure and Function

Part I (20 minutes)
Throughout the activities today, you will work in groups of three to four students.
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a) Which three general structures do they ALL have in common? (Choose from the list below.)

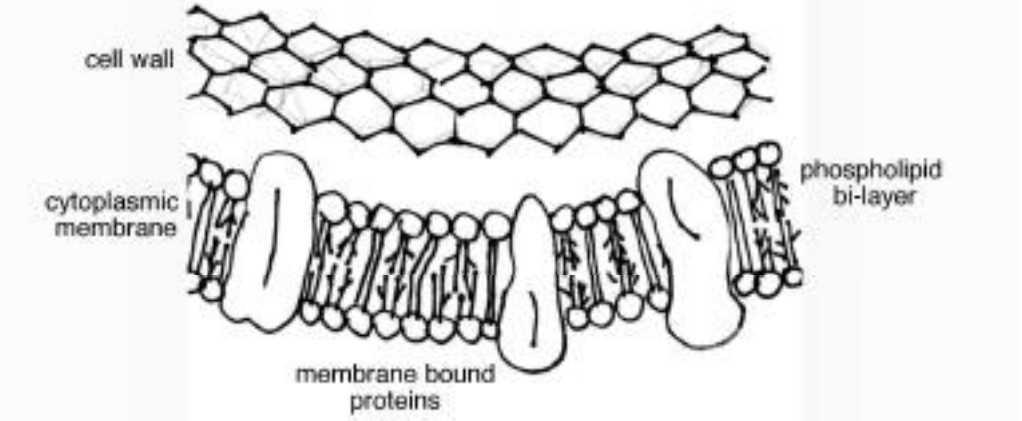
- **cell wall**
- **cytoplasmic membrane**
- **membrane-bound proteins**

b) What is the function of each of these three structures?

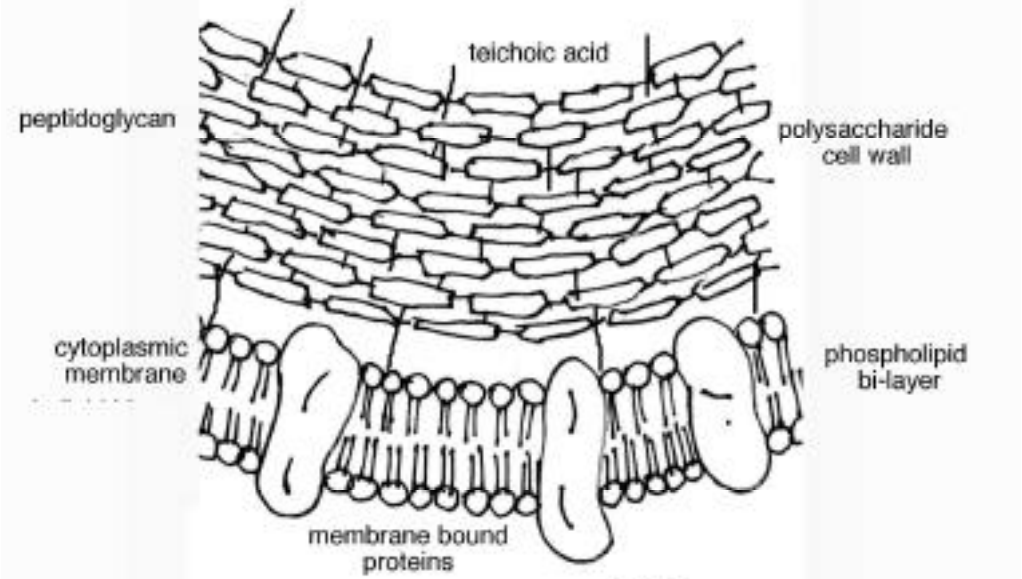
- **cell wall: provides structural support and protection**
- **cytoplasmic membrane: is the semi-permeable membrane that keeps most molecules out of the cell**
- **membrane-bound proteins: act as signal molecules, transporters, and energy-making machinery for the cell.**

Small Group Activity ANSWER KEY

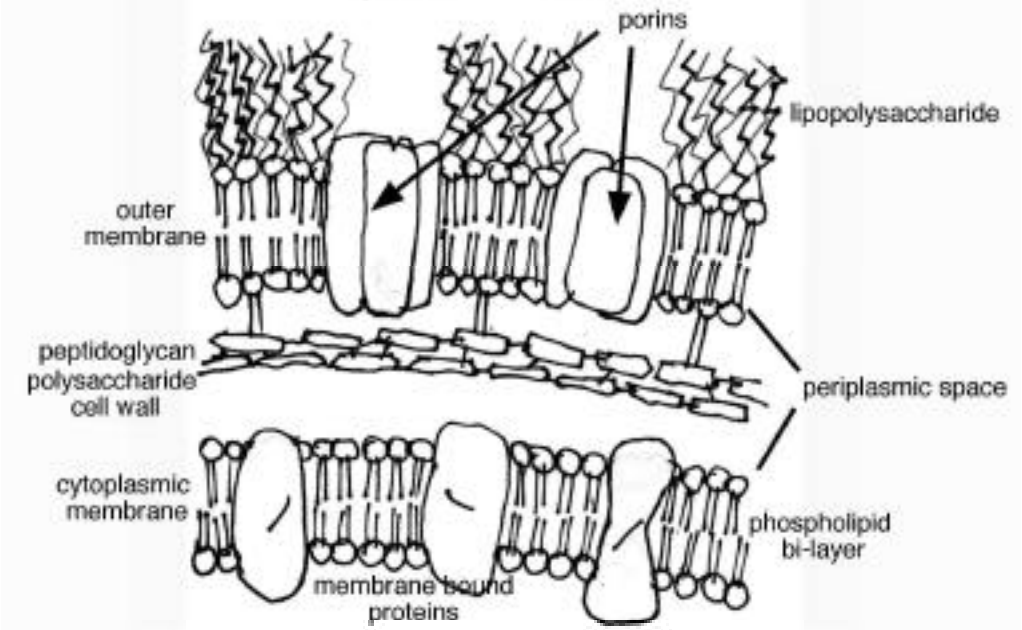
Cell type **ARCHAE**



Cell type **GRAM (-)**



Cell type **GRAM (+)**



Small Group Activity ANSWER KEY
Cell Structure and Function

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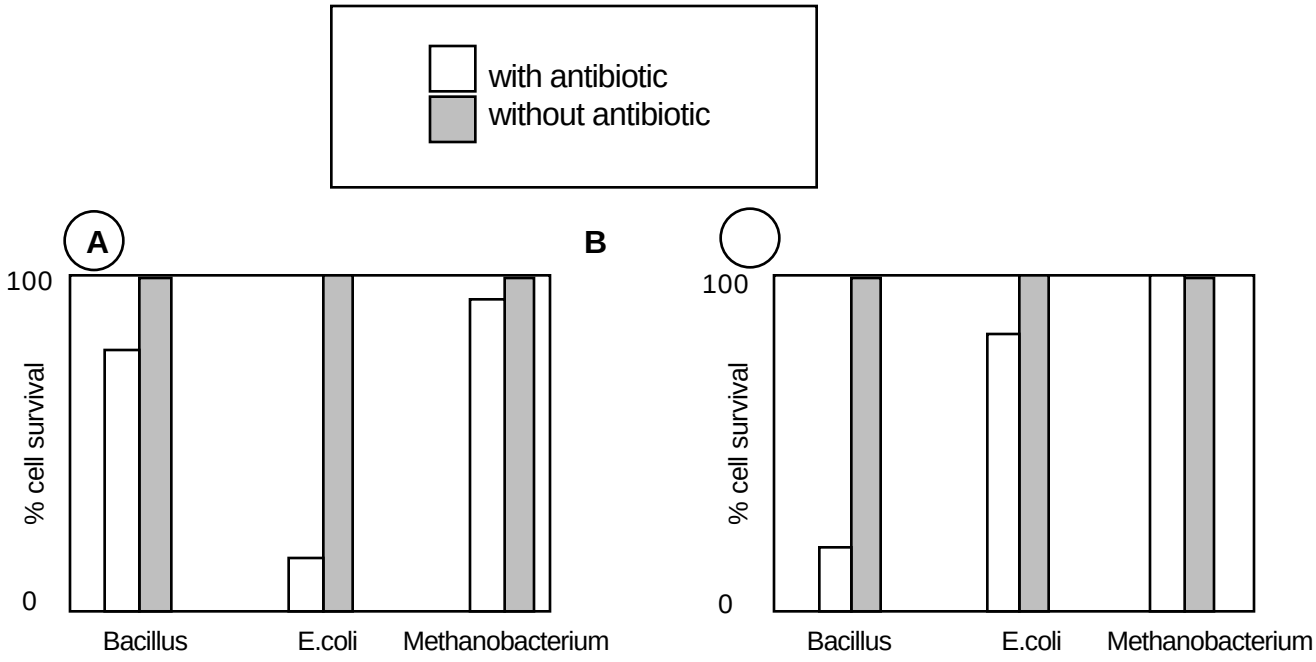

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Cell Structure and Function
Writing Assignment

Your name _____

Your instructor's name _____

QUESTION: According to the data on the previous page, which experiment (A or B) was done with vancomycin and which was done with polymyxin?

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Please limit your answer to the FRONT of this page.

Experiment A was done with polymyxin, Experiment B with vancomycin.

Experiment A:

Polymyxins are preferably bind to lipid A which is the predominant form of lipid in LPS and is only found in Gram(-) type outer membranes. Thus the Gram (-) *E.coli* will be greatly inhibited because its outer membrane, which is exposed and easily accessible to polymyxins, will bind polymyxins and be disrupted.

Bacillus, a Gram (+) type cell, and the Archaea, *Methanobacterium*, don't have lipid A, so will be much less affected.

Experiment B:

Vancomycin is specific for peptidoglycan. Gram(+) bacteria like *Bacillus* are greatly inhibited because they have peptidoglycan as their outermost layer so it is easily attacked by vancomycin. Gram (-) cells like *E.coli* have an outer membrane that protects the cell wall from vancomycin. Archaea don't have peptidoglycan cell walls.